puting a formula whose constants define the "standard atmosphere." *As already stated*, the values adopted for this purpose *should* be as nearly as possible true annual averages. These the meteorologist can furnish for many regions, principally for Europe and the United States, yet we find not infrequently "investigators" picking out a few observations here and there and spending (in effect *wasting*) much time and energy in computing formulæ for general application based thereon. An instance of this practice is to be found in a recent paper by M. Soreau,[1] in which he essays to establish "standard" free-air conditions. Unfortunately his results are based upon only *40* sounding balloon records, whereas some hundreds might have been used. Worse still, these 40 soundings are very poorly distributed as to season. There are 15 in the cold months January and February, 23 in the transitional months March to May, and only 2 in the one summer month of June, and even these 2 are in the early part of that month. It is not surprising, therefore, to find that the pressures at all heights above the surface are considerably below true annual averages.

Using his means M. Soreau evolves the following empiric equation:

$$Z = 5\ (3064 - 1.73\ P - 0.0011\ P^2)\ \log \frac{760}{P},$$

in which Z is the desired altitude and P the observed pressure. He states that this formula fits his mean values well, which is not surprising, since it is based upon them. It does not, however, fit any other values that have been published. Applied to those for Europe given by Dines,[2] the errors in determining Z are about 1.3 per cent; applied to those for the United States,[3] the errors are nearly 4 per cent. It is not to be expected, of course, that a single formula will apply to different, widely separated localities, but a formula for use in Europe should certainly be based upon representative European data. Otherwise, the conclusions mislead those not familiar with meteorological data. In a more recent note Rateau,[4] calls attention to discrepancies in Soreau's values and those given by Lapresle for Lindenberg, and expresses the hope that further information as to average free-air conditions may be obtained. As a matter of fact there is already sufficient information for this particular purpose, so far as Europe is concerned.

Naturally, the remainder of M. Soreau's paper, in which he discusses the relations between λ and μ (λ being the ratio of the specific gravity at Z altitude to that at the surface, and μ the corresponding ratio of pressures) is of little value, since it is based upon incomplete data.

Finally, a more acceptable discussion of the subject has been made by Prof. Pericle Gamba, who has employed a large number of observations in several countries, resulting in a reasonably close representation of the average conditions in the free air. Prof. Toussaint [5] has utilized Gamba's analysis of the meteorological data in the formulation of a proposed interallied agreement as to the law of decrease of temperature with increase of altitude. Toussaint proposes the adoption of a "law" of linear decrease of temperature with altitude, starting at a temperature of 15° C. at sea level and attaining −50° C. at an altitude of 10,000 meters. This "law" is expressed by the formula $t = 15 - 0.0065\ Z$, in which t = temperature in °C. and Z = altitude in meters.

Using this formula for computing the "standard" temperature for various heights, and assuming further that the atmosphere is dry and that gravity remains constant at all levels, the author quickly determines the appropriate values of pressure and density. The results are given, in abridged form, in the following table:

Altitude above mean sea level.	Pressure.	Temperature.	Density.
m.	*mm.*	°C.	*kg./cu.m.*
0	760	15	1.225
500	714.2	13	1.165
1,000	673.4	9	1.112
1,500	634	6	1.060
2,000	596.2	2	1.008
2,500	560	−1	0.957
3,000	525.7	−5	0.907
3,500	493	−8	0.865
4,000	462.2	−11	0.820
4,500	432.2	−14	0.778
5,000	405	−18	0.735
6,000	353.8	−24	0.660
7,000	307.8	−31	0.588
8,000	266.9	−37	0.525
9,000	230.4	−44	0.467
10,000	198.2	−50	0.413

Although the adopted rate of temperature decrease is arbitrary, the resulting values nevertheless agree quite well with annual means as published by various investigators for Europe and the United States. (*Cf.* references in footnotes 2 and 3.) Prof. Toussaint remarks:

> It has been found preferable to take a linear law rather than to seek an equation approximate to Prof. Gamba's curve, for the following reason:
>
> In order to define the standard atmosphere, what is needed is not an exact representation of that curve, but merely a law that can be conveniently applied and which is sufficiently in concordance with the means adhered to. By this method, corrections due to temperature will be as small as possible in calculations of airplane performances, and will be easy to calculate. The proposed law seems likely to realize such conditions.
>
> The deviation is of some slight importance only at altitudes below 1,000 meters, which altitudes are of little interest in aerial navigation. The simplicity of the formula largely compensates this inconvenience.
>
> It must be remarked, however, that since the isothermal layers seem to commence, in European regions, at an altitude of about 11,000 meters, it would be dangerous to extrapolate above that altitude.
>
> When it becomes an ordinary occurrence for airplanes to attain that altitude, it will be necessary to modify the law, but it suffices for the machines now in use.

It should be further remarked that the proposal is improperly referred to as a "law." A law is supposed to define something that is exact, within reasonable limits, whereas the actual conditions at different times and places will differ widely from this or any other assumed rate of decrease. "Standard atmosphere" is probably the best expression. It is to be hoped, though, that not even that term will be adopted, until all, or at any rate most, countries have agreed to use the same values.—*W. R. Gregg.*

INTERVALS BETWEEN BEGINNING OF RAINFALL IN WEST AND CENTRAL FRANCE.

A letter received from Albert Jagot, of Le Mans, France, gives an account of some interesting studies on the intervals between rainfall at Nantes and Le Mans and between Brest and Le Mans. By grouping low-pressure locations and high-pressure locations he has

[1] Lois expérimentales des variations de la pression barométrique et du poids spécifique de l'air avec l'altitude, par Rodolphe Soreau. *L'Aérophile*, Novembre 1-15, 1919, pp. 325-342. Also in briefer form in *Comptes Rendus*, December 1, 1919, pp. 1023-1025.

[2] Characteristics of the free atmosphere, W. H. Dines, F. R. S., *Geophysical Memoirs No. 13*, Meteorological Office, London, 1919, M. O. 220c. pp. 47-76.

[3] Kimball, H. H.: On the relations of atmospheric pressure, temperature, and density to altitude. MONTHLY WEATHER REVIEW, March, 1919, 47: 156-158.

Gregg, W. R.: Average free-air conditions as observed by means of kites at Drexel Aerological Station, Nebr., during the period Nov., 1915, to Dec., 1918, inclusive. MONTHLY WEATHER REVIEW, Jan., 1920, 48: 1-11.

[4] A. Rateau: Variations du poids spécifique de l'air avec l'altitude en atmosphére standard. *L'Aérophile*, Mars 1-15, 1920, pp. 72-73.

[5] Draft of interallied agreement on law adopted for the decrease of temperature with increase of altitude, Mar., 1920, Issued by Ministere de la Guerre, Aeronautique Militaire, Section Technique.

tabulated the number of times rainfall occurred at the two stations within 3 hours, 4 to 6, 6 to 8, 8 to 12, etc., hours. For the LOWS the table is as follows:

LOW centered over—	Hours interval between rain beginning at Nantes and Le Mans			
	0-3	4-6	6-8	8-12
1. British Isles	38	12	2	11
2. Netherlands	12	15	....	3
3. Norway, Iceland, Stornoway	10	5	4	1
4. Brittany, Straits of Dover, Western France	2	13	4	7
5. Sweden, Baltic Sea	7	....	2	....
	69	45	12	22

For HIGHS the following is the result:

HIGH centered over—	Hours interval between rain at Nantes and Le Mans			
	0-3	4-6	6-8	8-12
1. Spain, Gascony	36	12	11	7
2. Central Europe	30	5	21	4
3. Great Britain (with LOW over North Sea)	6	4	2	....
4. Southeast of Europe	2	6	....	2
	74	27	34	13

It is thus seen that the shorter interval, 0 to 3 hours, seems to prevail. At the time of the rainfalls which were compared, the winds in the most cases were from NW. to SSW. Similar studies were made for the interval between Brest and Le Mans, with the following result:

LOW centered as in—	Hours interval between rain at Brest and Le Mans			
	0-6	6-8	8-12	12-15
1 above	11	6	6	1
4 above	3	1	2	....
5 above	4	1	1	....
	18	8	9	1

HIGH centered as in—	Hours interval between rains at Brest and Le Mans			
	0-6	6-8	8-12	12-14
1 above	9	4	6	1
2 above	6	....	....	....
3 above	3	2	2	....
4 above	....	3	....	....
	18	9	8	1

Here, too, the prevailing interval is the shortest one, and the winds, says the writer, are the same as in the previous case. The distance between Nantes and Le Mans is 185 kilometers, and between Brest and Le Mans is about 420 kilometers.—*C. L. M.*

THE MOST INTENSE RAINFALL ON RECORD.[1]

By BENJAMIN C. KADEL.

Mr. H. G. Cornthwaite's article, "Panama Rainfall," in May, 1919, MONTHLY WEATHER REVIEW, 47: 298–320, contains in Table 1, Maximum rainfalls, a statement of the occurrence of 2.48 inches of rainfall in 5 minutes at Porto Bello, Panama, 2:07 a. m., November 29, 1911. The actual record has been kindly loaned to the Weather Bureau (see retouched photostat, fig. 1), and from it we learn that all but 0.01 inch fell in three minutes, or at a rate of 0.82 inch per minute. As this exceeds by 100 per cent the rate of 8.07 inches in 20 minutes at Curtea de Arges, Roumania, July 7, 1889, heretofore considered the world's record, it is desirable to record such facts as may have a bearing upon its validity.

The shower that includes the period under consideration fell at an excessive rate from 12:45 a. m. to 2:45 a. m., the total fall for the two hours exceeding 6 inches. The total rainfall for the 24-hour period ending at 5 p. m. was 7.60 inches by stick measurement. The 12-inch tipping bucket registering gage apparently functioned properly throughout the period, although the record for the three minutes is so blurred as to be illegible, the blurring being due to the slow clock speed rather than to instrumental failure. The actual fall during the period was determined by first correcting the legible portion of the 24-hour record on the basis of the previous performance of the gage, and in accord with accepted practice, then crediting the remainder to the excessive period. It is established by letters of inquiry, addressed by Dr. Brooks to Mr. Cornthwaite, that the gage was emptied at 5 p. m. before the rain began; that the instrument was in the hands of careful observers; that to enter both stick measurements and registration was the usual practice; that the water was regularly poured out at each observation; and that no foreign substance was found in the rain gage or in the funnel at the time the rain was measured. The record was promptly made the subject of special inquiry, and the officer in command states that in his opinion it is correct. Persons who were at work at the time remarked about the heavy rain, and low-lying ground was covered with several inches of water, drains not being capable of carrying it away as fast as it fell. Several large boulders were dislodged and washed down the hillsides, and the reservoir supplying the town with water overflowed. The record therefore appears to be well substantiated.

While the evidence supporting the validity of the record is sufficient under ordinary circumstances to warrant acceptance, it appears proper to set forth in this connection some reasons for doubting that the actual quantity of rain fell within the three minutes. The method of interpreting the record by the process of elimination means that any failure of the tipping bucket to register throughout the entire 24 hours would be credited to the three-minute period. Dr. Brooks counted 13 or 14 projections on the original record, which probably means 13 or 14 excursions of the zigzag pen, corresponding to 1.30 or 1.40 inch. The record is too blurred to be sure of more ups and downs. This agrees fairly well with the performance of a tipping bucket during an experiment at this office, during which 2.48 inches of water was poured into a similar rain-gage funnel, after which the lower end of the funnel was opened. The time required for the water to flow through the opening was 2 minutes and 15 seconds, and the tipping bucket made 194 tips during the process. The performance of the bucket was decidedly erratic, especially at first. Now, since the time occupied in discharging 2.48 through the small opening at the lower end of the funnel is nearly as

[1] Paper presented at meeting of the American Meteorological Society, Washington, D. C., Apr. 22, 1920.